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THE UNIVERSITY OF MICHIGAN
RADIO ASTRONOMY OBSERVATORY

Report No. 68-12

Data Reduction And Analysis Report
For The
Radio Astronomy Experiment
Aboard The OGO-II Spacecraft

F. T. Haddock
Director

August, 1968

Contract NAS5-3099

THE UNIVERSITY OF MICHIGAN ARTES SCIENTIA VERITAS 1817

DEPARTMENT OF ASTRONOMY

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SUMMARY

The Radio Astronomy Observatory of the University of Michigan has identical experiments on the OGO-II and OGO-IV spacecraft, whose primary objective is to generate a map of the cosmic noise background at a frequency of 2.5 MHz, using ionospheric focussing to provide resolution. Because of various spacecraft problems, it does not appear that the OGO-II experiment will achieve this objective. Therefore, the data from this experiment has not been fully processed. It is possible, however, that OGO-II data may be of some value to supplement that obtained from OGO-IV, or may yield valuable information on the earth's ionosphere.

OGO-II EXPERIMENT DATA ANALYSIS REPORT

I. INTRODUCTION

OGO-II (OGO-C) was the second spacecraft of the OGO (Orbiting Geophysical Observatory) series. It, and its sister craft, OGO-IV (OGO-D), were placed in orbits that were relatively low, slightly eccentric, and nearly polar. OGO is a complex spacecraft, designed to stabilize itself with respect to the sun and the earth. It embodies the "streetcar" philosophy, where the experimenter furnishes only the sensors and the necessary electronics to interface them with the central spacecraft telemetry system. The spacecraft provides primary power, telemetry, and facilities to receive and decode commands from ground stations. NASA's ground station network and data facilities are used to collect and edit the data, and separate that from different experiments. Experimenters receive data on magnetic tape, ready for computer processing.

The Radio Astronomy Observatory of the University of Michigan has identical experiments on the OGO-II and IV spacecraft, whose primary purpose is to map the cosmic noise at a frequency of 2.5 MHz., using ionospheric focussing to obtain directivity. Because of the high level of RF interference generated by the spacecraft, and because the spacecraft failed to stabilize, the OGO-II experiment has not achieved its primary objective, though there may be some secondary uses for the data.

Work on the flight package and data analysis for OGO-II and IV has been supported under NASA contract NAS5-3099.

II. BACKGROUND

A. Scientific Objectives, and Description of Experiment

Primary Purpose:

The primary purpose of the radio astronomy experiments on the OGO-II and OGO-IV spacecraft is to map the brightness distribution of cosmic radio noise over the sky at a frequency of 2.5 MHz, using a theoretically predicted focussing effect of the ionosphere to obtain a resolution of about 20°. An electrically short, essentially non-directional antenna is used on the spacecraft. To achieve this resolution at this frequency using a conventional directional antenna array would required orbiting a physical structure of dimensions greater than a mile (1750 meters).

Focussing Effect:

The theory of radio propagation in a plasma predicts that as a radiometer operating at a frequency of a few megahertz descends into the ionosphere, it will reach a point where cosmic radiation is no longer received, but is cut off by the ionosphere. The theory further predicts that as the radiometer approaches the cuttoff point, the portion of the celestial sphere that is "seen" by the radiometer - the effective "beam" of the antenna - is a circle at the local zenith which grows progressively smaller, shrinking to zero diameter at the cutoff point. In principle, then, one could achieve any desired resolution simply by sampling the radiometer at the appropriate time. In practice, small irregularities in the ionosphere, the necessity of averaging the radiometer output over a finite period of time, and the difficulty in determining just the right time to sample limit the practical resolution to perhaps 20°.

To use this focussing effect for mapping the celestial sphere requires that the radiometer move at least once through the appropriate levels of the upper ionosphere, either upward or downward, for every point on the map. A spacecraft in an appropriate eccentric orbit will, in principle, provide two such sample points per orbit. Slow, secular perturbations to the orbit will cause these two focussing points to move slowly about the sky, so that ultimately the entire celestial sphere will be surveyed.

To use the focussing effect for mapping requires accurate knowledge of the local distribution of electron density in the ionosphere, in order to identify the brief period in time when focussing occurs, and to separate the ordinary mode propagation from the extra-ordinary mode. Fortunately, the antenna itself serves as a probe to determine the local electron density at certain points. As the antenna moves downward into the ionosphere, several events occur which provide landmarks which give some clue to the local electron density. The first such event is the disappearance of the extra-ordinary mode contribution to the cosmic noise, which occurs abruptly at the point where $X = 1 - Y$. (For the definitions and significance of the plasma parameters X and Y, see, for example, Weil and Walsh, 1964.)

This point represents the transition from region 1 to region 2. In region 2, conspicuous changes occur in the antenna impedance, culminating in a rapid reversal of the sign of the reactive component and a maximum in the resistive component. These changes occur near the point where $X = 1 + Y^2$, which is the transition from region 2 to region 3. These changes in antenna impedance may be detected by direct measurement of the impedance, or may be inferred from the behavior of the radiometer channels, since the transfer of power from the antenna to the radiometer depends upon the antenna impedance.

These events occur independently at different frequencies, so a multifrequency experiment can yield several points on a curve of local electron density vs. time. It is then possible to interpolate to get a continuous function.

B. Experiment Package

The experiment package for the radio astronomy experiments on OGO-II and IV are described in detail in Ref. 1. The package consists of two radiometer channels, operating at frequencies of 2.0 and 2.5 MHz, respectively, and an antenna impedance meter which measures both the resistive and reactive components at 2.5 MHz. The antenna is a 60 ft. monopole, attached to the outer edge of one of the spacecraft solar panels, and extending outward parallel to the axis of the solar panel.

The 2.5 MHz radiometer and antenna impedance meter are so arranged that both can function simultaneously without mutual interference. The experiment normally operates continuously, with each of the four output signals being sampled by the spacecraft telemetry system approximately four times a second.

C. Outline of Data Analysis Plan

The planned procedure for analyzing OGO-II data to produce maps of the cosmic noise distribution includes five parts, as follows. Only Part 1 has been carried through for OGO-II data.

Part 1. Plot the experiment output on film. Evaluate the data from each orbit, and identify the "Selected Intervals" during each orbit when focussing should have occurred.

Part 2. Reduce the radiometer data for the selected intervals from telemetry units to mean square noise voltage at the radiometer input, and the antenna impedance data to resistance and reactance.

Part 3. Fit a model ionosphere to the observed data, and calculate better values for the antenna resistance. Correct for the impedance match between the antenna and radiometer, and for radiometer internal noise. Separate the ordinary and extra-ordinary modes. Determine the time when focussing occurred in the extra-ordinary mode, and the value of cosmic noise temperature observed at that time.

Part 4. Determine the effective region of the celestial sphere from which the antenna is receiving radiation (effective beam).

Part 5. Combine many such measurements into a map of cosmic noise temperature.

Parts 1 and 2 are rather straight-forward computer operations. Part 3 is a highly complex operation, for which no straight-forward algorithm exists. It requires scientific judgements, interspersed among extensive calculations. These judgements are in general based upon comparing experiment data with synthetic data produced by calculations, with both kinds of data presented in graphic form. Part 4 is also quite complex, and requires tracing rays through the ionosphere. Part 5 is straight forward.

Secondary objectives of the OGO-II experiment are to examine the behavior of an antenna in a plasma. Data reduction procedures have not been defined to achieve this end, but the procedure would involve comparing the observed behavior of the antenna with that predicted by the various theories.

III. HISTORY

A. Spacecraft History

OGO-II was launched from the Western Test Range at 13:11:55 UT on October 14, 1965. Due to loss of guidance data to the BTL ground guidance station, the Thor main engine shut down late, resulting in an orbit higher than planned.

	Desired	Achieved
Perigee	333.22 km	412.88 km
Apogee	926.41 km	1511.78 km
Inclination	86.004 degrees	87.359 degrees

The spacecraft attitude control system failed to properly track the earth's horizon. This resulted in a rapid loss of stabilizing gas and a period of three axis stabilization lasting only ten (10) days. The spacecraft was allowed to spin up, and eventually stabilized with a spin period of about 4 minutes about the Z axis. The spin axis was precessing about a cone with a half angle of 10 degrees in a period of 2.9 days.

The radio astronomy experiment (Exp. 5001) was turned on in Revolution 5, and the antenna was deployed in Revolution 89. We had only 3 to 4 days of data acquisition with the antenna deployed before stabilization was lost.

Actual orbit-attitude data is present for these latter 3-4 days, as is electron density data from experiment 5019. However, for the spin-stabilized time subsequent to this, there is neither attitude data nor electron density data available for correlation with our measured antenna impedance data. The prime purpose of the experiment, mapping the cosmic background by ionospheric focussing, is next to impossible to achieve without accurate attitudes and densities.

B. Data Analysis History

To map the cosmic noise distribution using the ionospheric focussing effect requires a data analysis procedure which makes it possible for a scientist to closely monitor and control the computation process. This is because it appears necessary to exercise scientific judgement at several points in the procedure. Consequently, the data reduction and analysis proposal submitted in November, 1964, (ref. 6) spelled out the requirement for a data reduction system with interactive capability. The proposed system consisted of a medium-sized computer, to which we proposed to attach special equipment of our own design to support the interactive operation.

Authorization to begin preparations to process OGO-II data was received from NASA in June 1965, four months before OGO-II was launched (October 1965). Approval to order the computer, however, was delayed until June 1966. The computer was installed in December 1966, and accepted April 1967. Thus it was about sixteen months after the OGO-II launch that we were able to perform the "first-part" processing procedure, to evaluate the data. Actually, processing was begun on a limited scale in February 1967, before the data system was fully operational. A total of 174 tapes were processed through the "first part" procedure before OGO-II was turned off in November 1967. Because of a variety of problems which are detailed below, no attempt has been made to carry out the original mapping experiment, and only a small quantity of OGO-II data has been processed further than the "first part" step.

IV. CONCLUSIONS

A. Prime Objectives

It appears unlikely that the prime objectives of the OGO-II experiment will be realized. Several problems exist, any one of which could render the experiment questionable.

First, the spacecraft failed to achieve the desired orbit, but instead is in an orbit substantially higher than intended. As a result, there are many orbits in which it does not dip far enough into the ionosphere for focussing to occur.

Second, the spacecraft failed to remain stabilized with respect to the earth, but has been operating in a spinning mode. Knowledge of the angle between the antenna and the earth's magnetic field is essential to the interpretation of the data, and this knowledge is unavailable for the spinning spacecraft.

Third, the level of internally-generated radio-frequency noise in OGO-II is so high that the radiometer channels are essentially saturated most of the time, reducing their sensitivity to cosmic noise to unacceptably low levels.

A fair sample of data (174 tapes) were carried through the first part of the reduction procedure, and the decision that the primary objective of cosmic mapping will not be achieved is based upon inspection the resulting plots.

There does remain the possibility that, after the analysis methods have been developed and checked out using OGO-IV data, there may appear an unexpected use for OGO-II data to supplement that obtained from OGO-IV.

Figures 1, 2 and 3 are examples of OGO-C data. Each figure shows the output of the four experiment channels during a short period of time near perigee. The four channels are, respectively, the 2.0 MHz radiometer, the 2.5 MHz radiometer, the "sine" channel and the "cosine" channel of the antenna impedance meter. The sine channel may be roughly identified with the antenna reactance, and the cosine channel with resistance, though this interpretation is not exact. Figure 1 shows an instance where the spacecraft actually dipped into the ionosphere far enough to pass through the critical level, so that focussing probably occurred. The most conspicuous indicator of the event is the sudden drop in the sine channel at $16^h52.5^m$, followed by a rise at $16^h57,5^m$. These abrupt changes in the sine channel output are identified with the crossing of the boundary between region 2 and region 3 in the X-Y^2 plane. Focussing should occur at an altitude just above this crossover, when the spacecraft is near the boundary between region 1 and 2. The perturbation in both impedance channels between 16^h53^m and 16^h54^m is an irregularity in the ionosphere.

On the particular orbit shown in Figure 1, the spacecraft dipped below the critical level in the ionosphere for a period of only about five minutes out of the orbit period of 104 minutes. On the example shown in Figure 2, the spacecraft apparently dipped into region 2, but did not cross the boundary between region 2 and region 3. Focussing may have occurred, but the fact that the spacecraft motion was mostly horizontal during the interval means that the interpretation of the data is virtually impossible. Figure 3 represents the case where even less penetration of the ionosphere occurred. In this case, the sine and cosine channels show only small rises, with no hint of the violent effects associated with passage through the critical layers.

If all other factors were favorable, a passage such as that in Figure 1 might yield the sky temperature at two points about 15° apart in the sky, but no sky temperatures could be deduced from passages such as those shown in Figure 2 and 3.

In all three examples, it may be noted that the output of the radiometer channels, particularly the 2.5 MHz channel, is always quite high, near the saturation level of 5.1 volts. It moves down below about 4.5 volts only as a result of the change in the impedance matching between the antenna and the radiometer when the antenna resistance, indicated by the cosine channel, is quite high. Outside the ionosphere, the output of the 2.5 MHz channel is typically above 4.75 volts, indicating antenna temperatures of the order of 10^{10} degrees, about two or three orders of magnitude greater than that which can be attributed to cosmic sources. We attribute this spuriously high level to electro-magnetic radiation which is internally generated in the spacecraft, and radiated to the antenna. It is very doubtful that any meaningful measures of cosmic noise can be deduced from this experiment in such an environment.

B. Secondary Objectives

It is possible that OGO-II data may be useful in achieving the secondary experiment objective of studying the behavior of an antenna in a plasma. The impedance-measuring channels are relatively immune to radio frequency interference, and hence their output is usable. The fact that the spacecraft is spinning, while presenting problems of interpretation, provides an unforeseen opportunity to study the effect of the angle between the antenna and the magnetic field, and also to search for effects of the "wake" of the spacecraft in the plasma. Used in this way, OGO-II data would supplement the data from OGO-IV in two valuable ways: by furnishing coverage during a different part of the sunspot cycle, and by covering a wide range of angle between the antenna and the magnetic field.

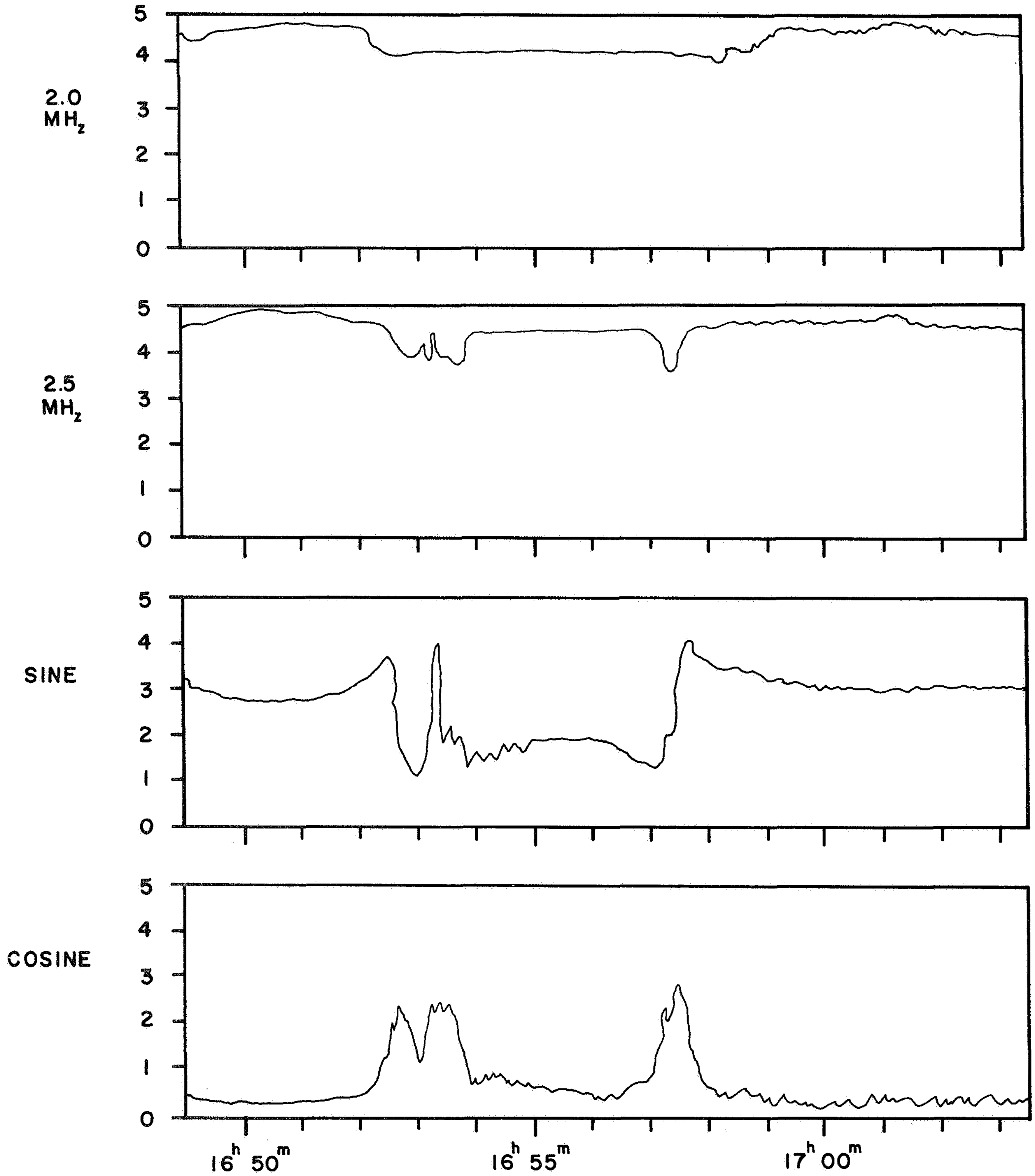

FIGURE 1. OGO-II RADIO ASTRONOMY EXPERIMENT DATA

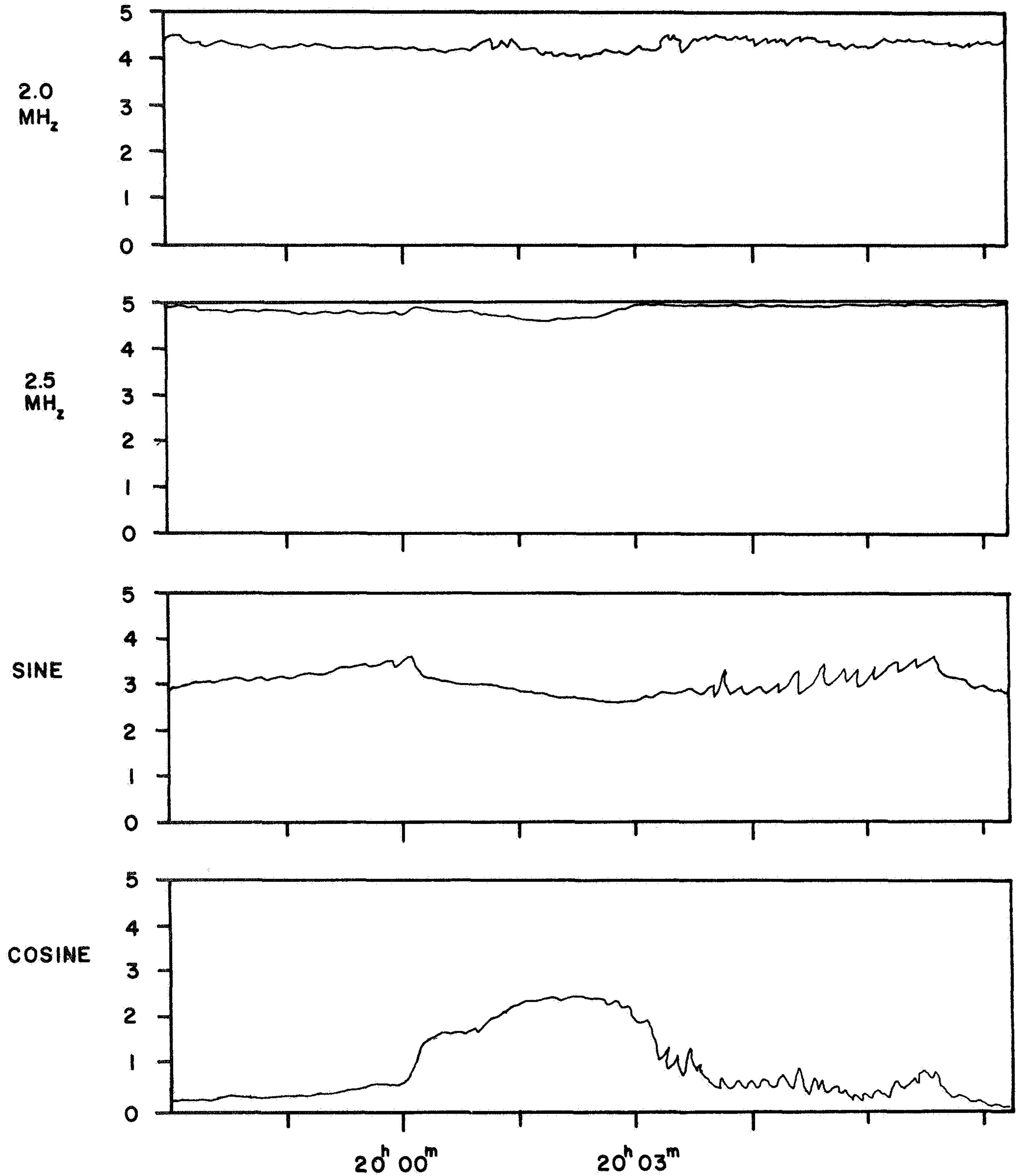

FIGURE 2. OGO-II RADIO ASTRONOMY EXPERIMENT DATA

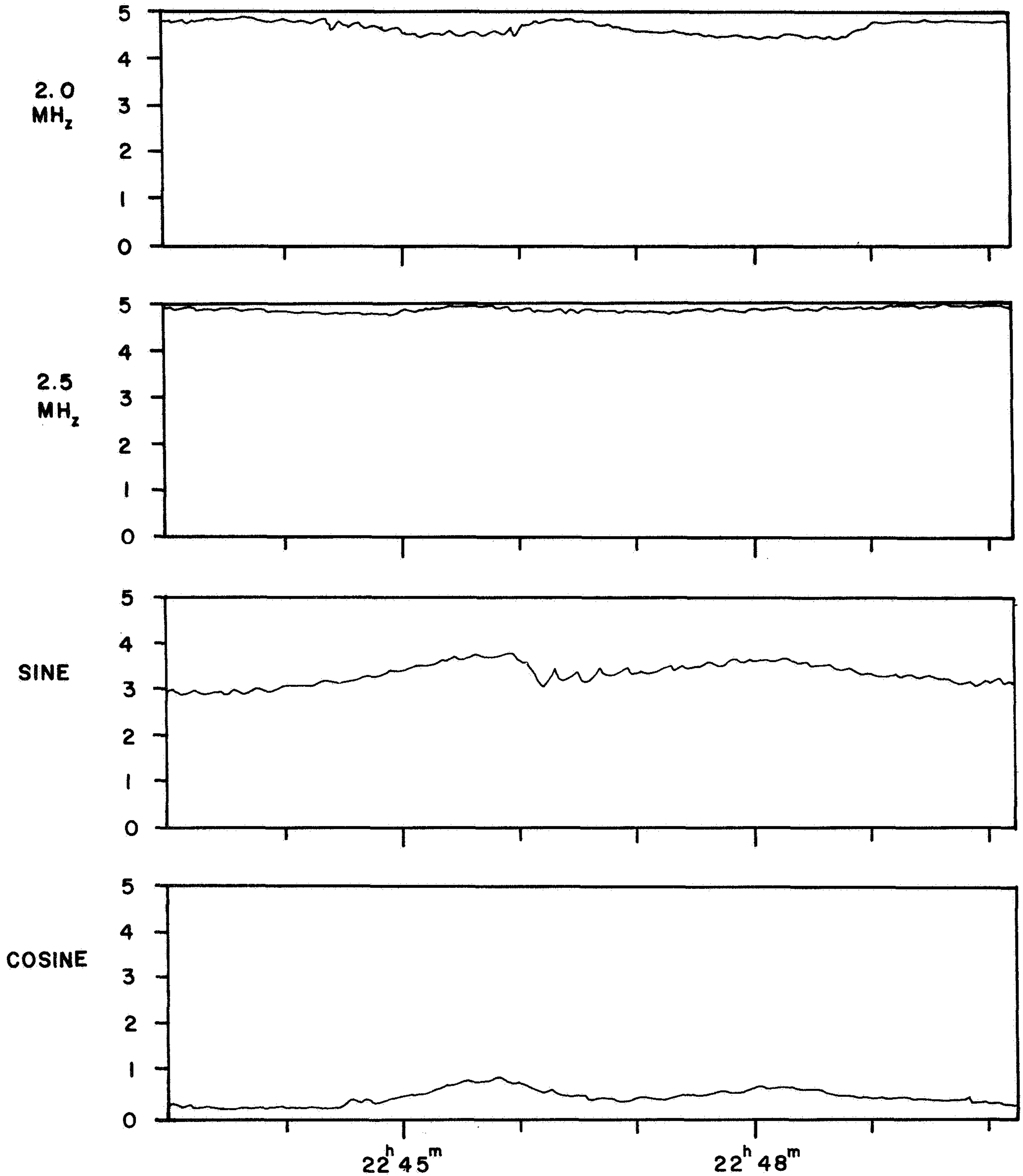

FIGURE 3. OGO-II RADIO ASTRONOMY EXPERIMENT DATA

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4. Instrumentation and Prelaunch Activity for a Radio Astronomy Experiment for POGO, submitted to GSFC, NASA, March, 1963.

5. POGO Extension Proposal, submitted to GSFC, NASA, April, 1964.

6. Proposal: Data Reduction and Analysis for OGO-C and D, submitted to GSFC, NASA, November, 1964.

7. Weil, H., and Walsh, D., Radiation Resistance of an Electric Dipole on a Magnetoionic Medium. IEEE Transactions on Antennas and Propagation, Vol. AP-12, No. 3., May, 1964.

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APPENDIX A
Special Data Processing Equipment

The Tape-to-Film Converter (TFC) was designed and built by the University of Michigan Radio Astronomy Laboratory. Its primary application has been to process information from the radio astronomy experiments on the OGO-A and B satellites, but it has also been used on the OGO-C and D experiments.

The TFC is required to accept digital data in the form of a magnetic tape prepared by a digital computer, and to record the data on 35 mm film as an analog plot in which the intensity of exposure varies with position on the film. In the normal mode of operation of the converter the data on the tape represent the intensity values only, and it is understood that successive intensity values are to appear in successive positions in rows across the width of the film, in a kind of a quantized raster, and that successive rows are to be displaced along the length of the film. The required resolution is equivalent to about 100 spots across the film, with a commensurate resolution in the direction along the film.

The major components of the TFC include the following:

1. Digital Magnetic Tape Unit
2. Cathode-Ray Oscilloscope
3. Automatic Camera
4. Timing and Control Unit
5. Data Registers and Counter Units

In the normal mode of operation, the film is held stationary with the camera shutters open, while data is read from the tape. As the tape is being read, a raster is generated on the cathode-ray tube and recorded on the film. Several records on the tape generate a single frame on the film. At the end of the generation of the frame, the tape unit halts and the film advances, ready to begin exposure of the next frame. A frame consists of a rectangular array of dots, 101 dots wide (across the film) and 120 long. A frame of 12,120 dots will correspond to a standard 35 mm double-frame picture.

The tape format used with the TFC is the standard IBM format such as used with IBM 729 tape transports. It has 6 bits per character, 6 characters per word and 200 or 556 characters per inch.

The general organization of the converter is illustrated in the block diagram, figure 1. The flow of data is from the Magnetic Tape Unit to the Data Register and Counter Unit, to the Cathode-Ray Tube Unit, and then to the Camera Unit. The Timer and Control Unit supervises and controls the operation of the converter.

The Data Register and Counter Unit contains the assembly register where each display word is assembled after reading 6 characters from tape; the hold registers which store the digital commands for the scope intensity and X and Y deflection amplifiers; control gates which are "enabled" to read coordinate instructions from the assembly register for X-Y mode words; and the digital-to-analog converters for intensity, X position and Y position signals.

The Cathode-Ray Tube Unit incorporates the necessary deflection and intensity amplifiers, and the power supply for the cathode-ray tube itself.

The Camera Unit consists of a 35 mm camera, its mounting, and the film transport mechanism which is controlled by signals from the Timer and Control Unit.

The Timer and Control Unit receives clock signals from the tape unit which are used to time the shifting of tape characters into the assembly register. Mode code bits from the assembly register are decoded in the Timer and Control Unit. Depending upon the mode a signal is provided to enable the control gates or to increment the X position hold register.

The Timer and Control Unit also provides start-stop signals to the tape transport and control signals to the Film Transport mechanism. The operator's control panel with various controls and indicators is also part of this unit.

In the original data which are to be plotted, the values of intensity corresponding to each point in the frame are known with a precision of 8 bits. We wish to preserve all 8 bits through the digital stages of the converter, and we therefore assigned 2 characters of each display word to represent each intensity value. Since each word is 6 characters long, each can contains three intensity values. As each new intensity value is shifted into position for display, the X hold register is incremented, moving the CRT beam one step to the right. At the end of the line the X register is reset to 0 and the Y register is incremented. Operations of the hardware in this manner is the standard and normal mode of raster generation. It is called raster mode.

It was found necessary to also provide certain other modes of operation. It was desired that the film record include title frames to help the scientist identify the data. The letters and numbers in the title frames are formed by dots but the dot positions are plotted by display words which contain X and Y position data as well as intensity information. In this mode in each display word there are 2 characters for intensity, 2 characters for X and 2 characters for Y.

The hardware can distinguish between raster words and X-Y words by use of a 4 bit code in each word. The 4 unused bits in the first set of intensity characters are used to specify the mode or kind of display word.

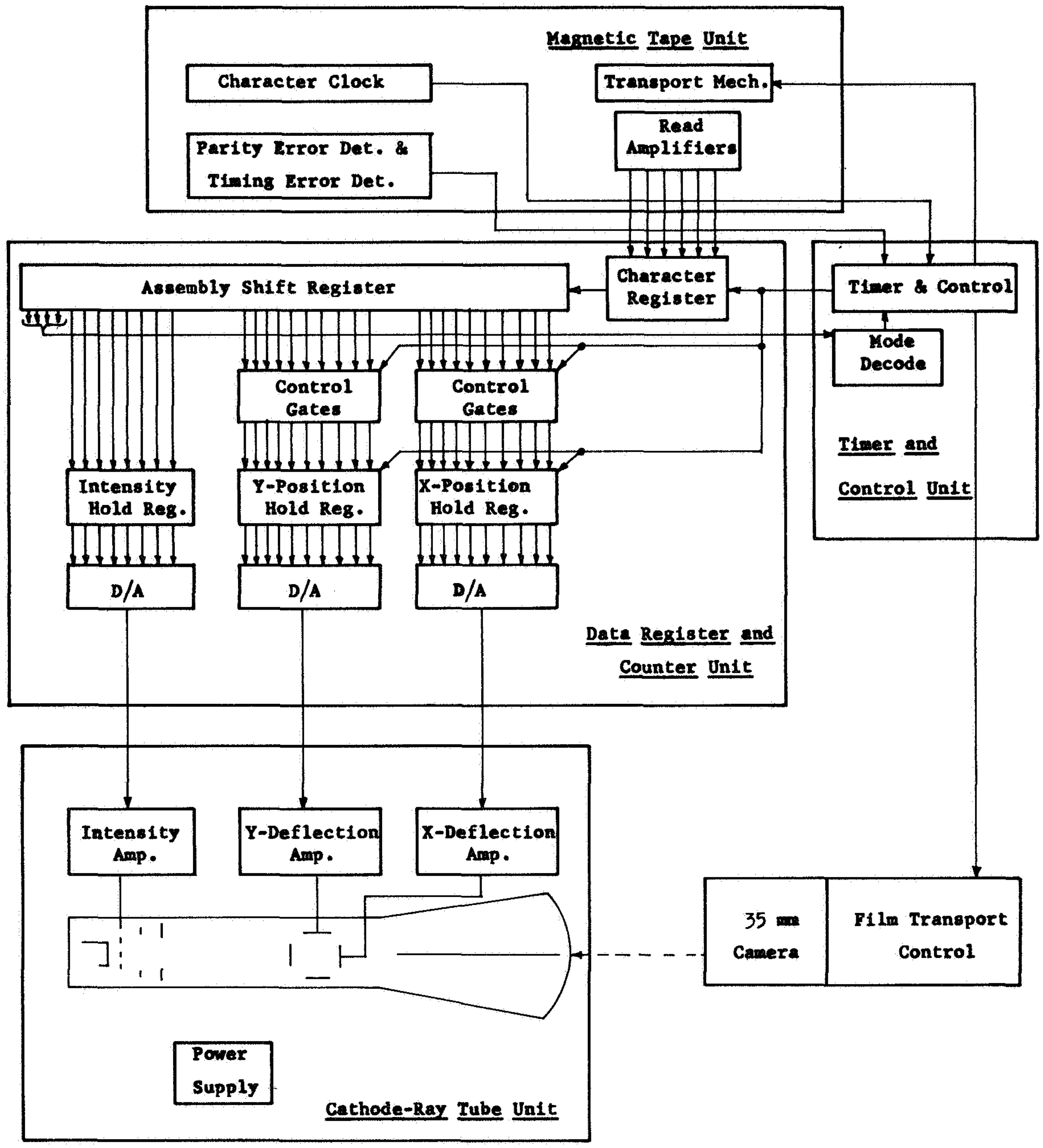

Fig. 1 BLOCK DIAGRAM - TAPE-TO-FILM CONVERTER

APPENDIX B

COMPUTER PROGRAMS FOR OGO-C DATA REDUCTION

INTRODUCTION

Part 1 of the data reduction procedure requires a computer program to prepare the data for input to the tape-to-film converter. This program reads data from the decommutated experiment tape, which is prepared at GSFC, and generates an output tape from which the tape-to-film converter can generate the appropriate plots on 35 mm film. The program was written in machine language for the SDS 930 computer, and was checked out concurrently with the acceptance testing of the machine. It has been used to process OGO-C data, and, with some modifications, to process OGO-D data also.

PROGRAM ORGANIZATION

The entire software package consists of a main program and 17 externally defined packages. All packages are written in SYMBOL. A brief description of each follows:

Main Program: A 3 card program which calls in all the subroutines.

PGO1ST: Is essentially the main program, in that it controls all the processing of the data. It initializes the whole procedure, reading in the parameter cards whenever necessary. All input from the Goddard tapes is checked first by PGO1ST, which determines whether it is a label record, data record, end of file, or end of tape, and then routes it through the programs accordingly. For a label record, the kilobit rate is checked, only four kilobit data (playback) being processed. The station number, year, day number, and time are read from the label record and given to TITLE for printing. If the day number on the label record is bad the first good day number on the data records following is used and then given to TITLE. All data records are processed by PROC, a count being kept by PGO1ST so that after 2 sets of 84 records, i.e., one orbit, a new title may be put out. Again, TITLE is not called until a good day number has been found. At the end of a file, PGO1ST prints out on the line printer the start and stop times for the file and the number of records in the file. At the end of an input tape, a new one is mounted, a new input card is read, and the whole procedure is restarted.

CONVER: Converts time given on the input tape in milliseconds to minutes.

BLDTBL: Builds a table of perigees for a given day, generally a new table for each new day on the input tape. The routine is given the first perigee of the day and keeps adding 104 minutes, i.e., one orbit, to it to make up one day.

PREPTT: Is given the start time of the data and, using the table built by BLDTBL, calculates the time intervals in minutes between the start time and the immediately preceeding perigee time.

TIMECH: Checks the data word for fill data, blanks, and negative values. If the data falls in any of these 3 categories, an error switch is set, leaving it up to the calling program to test the switch.

TITLE: Sets up a title record for each orbit to be written onto the output tape. Full output vectors are written on tape followed by a partial vector if necessary. Each vector is followed by an unconditional film-advance-code.

The following information is displayed by TITLE in the given order: Satellite Identification, Station Number, Tape Number, File Number, Record Number, Date and Start Time of the following orbit, time that elapsed since the last perigee occurred in minutes. Start time is displayed in hours and minutes on a 24 hour scale.

The size and intensity of the characters are fixed at size 5 and intensity 77_8.

PROC: Converts both radiometer channels and both impedance channels to coordinates for plotting on the TFC;

Ex. - for N = 16, an input record of 792 24-bit words reduces to an output record of 48 24-bit words;

puts an unconditional film advance code on the output tape after every 84 input records of each file and at the end of each input file; other output records are separated by conditional film advance codes.

GRID: Sets up a grid to be written on the output tape. Vertical grid lines appear at 0, 10, 20, 30, 40, and 50 minute intervals. Horizontal grid lines are at 0, 1, 2, 3, 4 and 5.1 volts. Two sets of horizontal grid lines are drawn, one above the other.

PGOLAB: Generates a descriptive print out of a POGO label record and converts the label record from BCD to SDS internal code.

PGORD: Reads in one record from GSFC input tape, does not check for parity errors and does not buffer the input; the calling program specifies the starting location into which the record is to be read; the number of words read in is returned in the zeroth location of the vector specified; a word count of zero indicates a file mark was read; when two EOF's are detected, the tape is rewound and a new tape is called for on the typewriter.

PGOPRT: Prints out on line printer line images specified by a TEXT statement in calling program; variables are inserted in the line images in the order given by the NOP's; a delete sign (0-7-8-punch) is used whenever a variable is to be inserted, a stop sign (12-7-8-punch) is used to terminate the line image.

PGOCRD: Reads card images using the SDS routine CDR and converts the information from SDS internal code into integers by means of the University of Chicago routine CNDBI. All numbers are integers right justified and packed in I8 fields (no space between); the information on the cards is read into the locations LOC_1 ... LOC_N specified by the calling program, with LOC_o containing the number of words read; a blank field terminates reading.

PGOTYP: Types out line images on the typewriter; used to type error comments and notes to the operator.

PGOWRT: Writes a specified output vector on magnetic tape, where the starting location and the number of words are specified by the calling program.

SKPFIL: Skips one file on the input tape.

BDEC: Converts a given binary number to integer; received from University of Chicago.

CNDBI: Performs decimal to binary conversions; received from University of Chicago.

RDUMP: Prints out specified locations on the line printer in octal form, where the first and last location to be printed are furnished by the calling program.

USE

All the subroutines needed are on the POGO SYSTEMS tape; the main program is in binary form on paper tape and must be read in each time.

INPUT DATA

Each data card contains 4 integers in I8 fields, where the numbers are:

1. Day number: DAYNO
2. Minutes past midnight of the first perigee; PER
3. UM/RAO tape number of the GSFC data tape being read; TAPENO
4. Number of points to be averaged; AVG

A new card is needed whenever a new input tape is mounted and whenever the time on the input tape changes from one day to the next.

OUTPUT DATA

Magnetic Tape: An output tape is written for display on the TFC; the ratio of input to output tapes is 10 or 15 to 1; the output tape consists of groups of 3 pictures, a label followed by 2 sets of 52 minutes of data, i.e., a label followed by one orbit.

The 2.0 MHz channel and the sine channel are plotted on the upper 0-5.1 volt scale, with the 2.5 MHz channel and the cosine channel on the lower 0-5.1 volt scale. (See description above of PROC and TITLE for more specific details).

Line Printer: The label record from the beginning of each file on the input tape is printed. Other printing includes the number of records per file, the number or bit errors for each 52 minutes of data, and the start and stop time of each file.

EXTERNAL DEFINITIONS:

PGO1ST, CONVER, TITLE, PREPTT, PROC, GRID, PGOLAB, PGORD, PGOPRT, PGOCRD, SKPFIL, PGOTYP, PGOWRT, BDEC, CNDBI, RDUMP, TIMECH, BLDTBL

EXTERNAL REFERENCES:

ISUE, OSAL

POPS USED:

RFG, SFG, OFT

SUBROUTINES CALLED:

MTAPE, PRINT, CDR, PTYIO

TIME:

An average data tape takes about 10 minutes for processing.

STORAGE REQUIRED:

MAIN	1	PGOPRT	355_8
BDEC	45_8	PGOCRD	103_8
GRID	1601_8	PGOTYP	116_8
TITLE	1175_8	PGO1ST	3017_8
PROC	500_8	TIMECH	33_8
RDUMP	250_8	CONVER	26_8
PGOLAB	553_8	PREPTT	71_8
CNDBI	101_8	BLDTBL	22_8

PGORD, PGOWRT, SKPFIL - 151_8

TOTAL: 10534_8

with MTAPE, PRINT CDR, PTYIO - 13352_8